BEYOND PESTICIDES
701 E Street, SE ▪ Washington DC 20003
202-543-5450 phone ▪ 202-543-4791 fax
info@beyondpesticides.org ▪ www.beyondpesticides.org

Can Schools be Opened Safely During the COVID-19 Pandemic?

The push to reopen schools

Despite pressure to reopen schools, concerns persist about the threat to the health of children, teachers, school staff, and families.[1] The American Academy of Pediatrics (AAP) has taken the position "that all policy considerations for the coming school year should start with a goal of having students physically present in school."[2]

There are many complex social, scientific, and logistical issues involved in a decision to reopen schools for in-person teaching. The National Education Association (NEA),[3] American Federation of Teachers (AFT),[4] National Parent and Teacher Association (PTA),[5] and others[6] call for a well-thought-out approach to reopening schools only when it is shown to be safe for all. Criteria mentioned by these organizations include:

- The pandemic is under control in the community—as evidenced, for example, by an **average daily community infection rate among those tested for COVID-19 below 5 percent and a transmission rate below 1 percent.**
- Protections have been put in place to keep the virus under control and protect students and staff. These include accommodations for students and staff at high risk; measures and building retrofits to protect against all forms of transmission; procedures for detecting disease, quarantining, and notification; involvement of families and educators in decisions; monitoring; and enforcement.
- Plans are in place that ensure continuous learning equitably for all students, with training for educators, families, and students in the process of virtual instruction, and access to devices and high-speed internet for every student and teacher.

From a practical perspective, the question of whether schools can comply with public health recommendations looms large. How do schools operationalize student use of face masks, distancing, and manage surface and air contamination with the virus?

Who is at risk?

Risks of COVID-19

The risks of reopening schools come from both COVID-19, caused by the SARS-CoV-2 virus, and the measures that schools may take to protect students, family members, teachers, and staff. The health risks from the virus to young children (elementary school age) appear to be smaller than the risks to adults, although transmission or spread of the virus to adults is of concern to public health officials.[7]

A preliminary investigation of U.S. pediatric COVID-19 cases finds that relatively few children are hospitalized with COVID-19, and fewer children than adults experience fever, cough, or shortness of breath.[8] However, severe outcomes, including death, are reported in children.[9] A relatively rare consequence of COVID-19 in children and adolescence is multisystem inflammatory syndrome, which can produce serious and life-threatening illness.[10]

In view of the epidemic of asthma,[11] the risk of asthmatic children contracting COVID-19 is another consideration. Research on the connections between asthma and COVID-19 points in different directions.[12] The strongest connection between asthma and COVID-19 involves non-allergenic asthma.[13] While most asthma in children is associated with allergies,[14] there remain questions about chemical exposures initiating or promoting asthma.[15]

In spite of the low incidence of serious illness, many children are infected with the virus without expressing symptoms, or before expressing symptoms. Asymptomatic persons, including children, may carry a high viral load.[16] Children may infect teachers and other workers in the school. If they become infected, they may bring the disease home, where they may transmit the virus to parents, grandparents, and other vulnerable family members.

Risks of Disinfectants and Disinfecting

As schools closed earlier in the year, attention was focused on virus-contaminated surfaces. While EPA has certified a large number of disinfectants as effective against SARS-CoV-2 (List N),[17] many of these chemicals are hazardous and actually weaken the respiratory, immune, and nervous systems.[18] At the same time, there are many safer disinfectants on EPA's list that are effective against the virus.

As the science shows, some people are more vulnerable to the effects of the virus than others. These are generally people who have a preexisting condition, comorbidities, or are of advanced age, who may have a weakened immune or respiratory system. With the management of viral and bacterial infections, it is always important not to exacerbate the risk to individuals in the process of avoiding or controlling the threat. In the case of COVID-19, there are measures of protection—both practices and

Some Hazardous Disinfectants

Disinfectants that affect the respiratory and immune systems are especially hazardous during the pandemic and should be avoided. The following are some of the worst.

Quaternary ammonium compounds (QACs or quats) include several disinfectants on List N. Quats are mutagens and reproductive toxicants and are known to increase the risk of asthma and allergic sensitization. Known genes for microbial resistance to quats may also contribute to antibiotic resistance.

Chlorine compounds include household bleach (sodium hypochlorite), chlorine dioxide, and hypochlorous acid. They can irritate eyes, burn respiratory tissues, and contribute to asthma.

Phenolic compounds include a wide range of toxic chemicals, including cresols, hexachlorobenzene, and chlorophenols. Health effects from breathing or exposure to the skin include headaches, burning eyes, muscle tremors, skin burns, irregular heartbeat, severe injury to heart, liver, kidneys, and lungs, cancer, and death.

Peroxyacetic acid (peracetic acid) acts quickly against all microorganisms and lacks harmful breakdown products. However, it is considered by the Association of Occupational and Environmental Clinics to cause asthma by respiratory sensitization and can cause dangerous damage to eyes and skin.

products—that can provide protection without using toxic products that increase risk factors. Beyond Pesticides continues to evaluate materials on EPA's List N, with a focus on avoiding those that threaten immune and respiratory systems.

Fogging and Misting

In terms of disinfecting surfaces, where half-lives (an indicator of the time of potential exposure) of the virus range up to 6.8 hours,[19] school districts have been concerned with the costs involved in repeated disinfectant applications. In the interest of disinfecting many classrooms quickly, schools have been investigating, and sometimes investing in, devices that apply disinfectants as a fog or fine mist into the indoor ambient air. Such devices pose special risks, as a result of inhalation or absorption from resulting surface residues.

Fogging reduces disinfectant efficacy. First, devices are not registered by EPA. This includes ozone generators and UV lights. It also includes some application devices like foggers. EPA does not generally recommend fogging applications, or wide area spraying of disinfectants, to control COVID-19 and warns, "A disinfectant product's safety and effectiveness may change based on how it is used. If a pesticide product's label does not include disinfection directions for use with fogging, fumigation, wide-area, or electrostatic spraying, EPA has not reviewed any data on whether the product is safe and effective when used by those methods."[20] In 2013, EPA sent a letter requesting supporting data to those manufacturers whose antimicrobial (disinfection) products claim to control microorganisms when applied by fogging or misting. EPA cites the following reasons for believing that fogging and misting are not adequately effective:[21]

- Application by fogging/misting results in much smaller particle sizes, different surface coverage characteristics, and potentially reduced efficacy when compared to sanitization or disinfection product applications by spraying, sponging, wiping, or mopping.

- The absence of pre-cleaning in the presence of soil contamination, potential reaction with or absorption of the active ingredient for different surfaces, and humidity/temperature fluctuations can also impact distribution and efficacy of the product.

- A surface treated by fogging/misting does not receive the same amount of active ingredient per unit area as the standard methods of application and, as a result, product efficacy may be greatly reduced.

Cleaning must precede disinfecting. Second, in order to be effective, disinfectants must be applied to clean surfaces. EPA refers to CDC's recommendation to clean and disinfect surfaces, using a detergent or soap and water prior to disinfection.[22]

Fogging and aerosols adversely affect lungs. Finally, fogs and fine mists are aerosols of very small particles that can be carried deep into the lungs, where they cause more damage.

According to the American Lung Association, "The differences in size make a big difference in where particles affect us. Our natural defenses help us to cough or sneeze some coarse particles out of our bodies. However, those defenses do not keep out smaller fine or ultrafine particles. These particles get trapped in the lungs, while the smallest are so minute that they can pass through the lungs into the bloodstream, just like the essential oxygen molecules we need to survive." Foggers produce a distribution of droplet sizes of 15-60 um.[23]

Electrostatic Sprayers

Electrostatic sprayers apply a positive charge to an area-wide spray as it leaves the nozzle, which causes droplets to be attracted to negatively charged surfaces. Users claim better, 360 degree, coverage when using electrostatic sprayers to disinfect a room.[24] EPA has made it a priority to evaluate electrostatic sprayers as a delivery mechanism for disinfectants on List N.[25] Canadian research shows that application of disinfectant with an electrostatic sprayer can reduce microorganisms on student desks by 41% when used alone as opposed to conventional cleaning and disinfecting, which reduces microbes by 42%. Electrostatic application of disinfectant after conventional surface cleaning and disinfecting can reduce virus levels by an additional 26%.[26]

Fogging does not save labor time. There are several caveats to the use of electrostatic sprayers. First, charged particles may be deposited on the applicator, including in the nose, so personal protective equipment (PPE), said to be optional in advertising, should be used.[27, 28] Second, CDC recommends cleaning first to ensure greater efficacy of disinfecting, and it is not clear that spraying disinfectant saves very much time if it is necessary to first clean the surfaces. Paper and other absorbent materials must be removed from the space where the spraying is conducted.[29] Finally, as the numbers above show, electrostatic application of disinfectant is not as effective as conventional cleaning and disinfection.

In the future, it is possible that electrostatic sprayers may improve, and be subject to independent efficacy review by EPA. The issues of the need to pre-clean, remove papers, and provide PPE will remain. Thus, if the goal is to provide a quick application method that does not require hands-on treatment, then no area-wide spraying is adequate at this time.

The Spread of Covid-19 is Mostly Airborne

We now know that the spread of the SARS-CoV-2 virus is mainly person-to-person through the air, although spread through contaminated surfaces does play a role. The virus can remain infective as aerosol for at least three hours (half-life of about 1.1 to 1.2 hours), though with some loss of infectiveness.[30] A recent study finds, "replication of SARS-CoV-2 in older children leads to similar levels of viral nucleic acid as adults, but significantly greater amounts of viral nucleic acid are detected in children younger than 5 years."[31] With average class sizes ranging from 15 to 24 students across elementary and secondary schools,[32] and an average class time of more than 6 hours per day,[33] the potential for spread of the virus can be great in the absence of controls of airborne virus. None of the disinfectants—even those applied as fog—control airborne virus.[34]

Minimizing risk of reopening

School Buildings

In school buildings, where both surfaces and air can serve as sources of infection, schools must pay attention to both routes of exposure. It is important, in disinfecting surfaces, to choose both a disinfectant and a mode of application that do not add risk to students, teachers, and custodial staff. Beyond Pesticides reviews disinfectant materials and updates recommendations regularly on our website.[35]

We do not recommend application of disinfectants as a fog or mist. Legally, a disinfectant may not be applied as a fog or mist unless labeled for such a use. In addition, some disinfectants, while labeled for fogging, may not kill the coronavirus. EPA's List N tells which application methods are considered effective, in the column labeled, "To kill SARS-CoV-2 (COVID-19), follow disinfection directions for the following pathogen(s)." Electrostatic spraying, as discussed above, is thus far an unproven technology. EPA recommends that those with asthma or other respiratory conditions "[u]se products that could reduce your inhalation exposure, such as wipes or dampened towels, to disinfect surfaces. These options will substantially lower inhalation exposure compared to sprays, which generate aerosols."[36] There does not appear to be a short cut to cleaning and disinfecting safely and effectively.

The safest way to minimize the chance of contracting COVID-19 through the air is to minimize time spent indoors where infected individuals are or may have been and practice social distancing with masks when with others both indoors and outdoors. Schools that do decide to reopen indoor classrooms for in-person instruction will need to take precautions to remove viruses from the air. If schools can be retrofitted with engineering controls for air exchange and filtration, virus removal may be maximized.[37] Such removal will still require the use of social distancing and face coverings in order to minimize exposure from larger droplets that do not remain suspended in the air, as well as surface cleaning and disinfection and handwashing.[38]

Engineering controls include increasing ventilation with outside air, improving natural ventilation, use of evaporative coolers in hot, dry climates, improving the HVAC (heating, ventilation, and air conditioning) system, and use of a portable air cleaner or purifier.[39] Ultraviolet (UV) light is also being investigated for its effectiveness in deactivating the virus. Critically, it is important to pay attention to patterns of air flow as well as rates of ventilation and purification. One early indicator of the importance of airborne transmission of the virus came from a restaurant in Guangzhou, China, where a presymptomatic person infected ten others who were downwind of the infected person in the air conditioning airflow.[40] The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) offers advice to retrofit and improve HVAC systems.[41] ASHRAE recommendations include:

- Use the highest filtering efficiency (minimum efficiency reporting value, or MERV) consistent with the specification of the HVAC system. HEPA or MERV 13 is

recommended minimum if equipment can accommodate pressure drop and MERV 14 is preferred.[42]
- Introduce portable, all electric HEPA/UV machines in each classroom, with at least two air rotations per hour.
- Ensure flow patterns maximize mixing of air in classrooms.
- Change the start of operation hours (e.g. change 6 am start to 4 am).
- Run dedicated outdoor air systems for two hours before and after occupancy.
- If possible, designate a "Purge/Flush" mode for operations to minimize the virus transmission via HVAC systems.
- Follow ASHRAE guidelines for energy recovery.[43]

Transportation

Transportation cannot be ignored because it is an area of high transmission with numerous touch points and shared air space, raising similar issues to building spaces. Increased use of private transportation to schools measure will increase air pollution (which aggravates the respiratory system) and place higher burdens on those who cannot afford it. ASHRAE offers guidance for safe travel and maintenance of systems on transit vehicles.[44] In addition to the personal measures of distancing, wearing face coverings, and washing hands, the organization suggests:

- Ventilation should be adjusted to the maximum consistent with the equipment's design.
- Allow operable windows to increase air flow.
- Change to HEPA (high efficiency particulate air) filters, but only when consistent with the manufacturer's recommendations, in order to avoid damage and voiding of the warranty.
- Follow recommended maintenance practices.

ASHRAE does <u>not</u> recommend use of UV disinfection in mass transit vehicles because it can cause break down of some materials, is potentially harmful to humans if they are directly exposed, and requires specific application times to be effective.[45]

Costs

Reopening schools safely will not be cheap. A report issued by the Government Accountability Office (GAO) on June 4, 2020 finds, "About half (an estimated 54 percent) of public school districts need to update or replace multiple building systems or features in their schools, according to GAO's national survey of school districts." The upgrades or retrofits needed in an attempt to protect students and staff from the coronavirus are in addition to GAO-cited repairs, although in some cases—such as the 41% of upgrades needed for HVAC systems—COVID-19 protection could take the place of already-needed upgrades. Nevertheless, additional funding will be required to make facilities and transportation safer and pay for day-to-day maintenance and disinfection.

Conclusion

While individual schools and school districts face difficult decisions regarding the need to reopen schools, doing so safely will require an investment in infrastructure and staffing. Unfortunately, because of elevated rates of infection and a lack of uniformity in the use of preventive measures (masks and distancing), schools do not exist in a vacuum and face serious challenges in maintaining a safe space for children, teachers, staff, and their families within a wider community environment in which the virus may be widespread.

ENDNOTES

[1] https://www.nytimes.com/2020/07/24/us/politics/trump-polling-schools-reopen.html.

[2] https://services.aap.org/en/pages/2019-novel-coronavirus-covid-19-infections/clinical-guidance/covid-19-planning-considerations-return-to-in-person-education-in-schools/.

[3] https://educatingthroughcrisis.org/wp-content/uploads/2020/07/NEA-Where-We-Stand.pdf.

[4] https://www.aft.org/resolution/safely-reopening-schools.

[5] https://www.pta.org/docs/default-source/files/advocacy/position-statements/reopening-schools-for-2020-2021-ps.pdf.

[6] https://www.brookings.edu/blog/the-avenue/2020/07/24/to-reopen-safely-schools-must-protect-more-than-just-students-and-teachers/.

[7] https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/prepare-safe-return.html.

[8] Coronavirus Disease 2019 in Children — United States, February 12–April 2, 2020 https://www.cdc.gov/mmwr/volumes/69/wr/mm6914e4.htm?s_cid=mm6914e4_w

[9] Coronavirus Disease 2019 in Children — United States, February 12–April 2, 2020 https://www.cdc.gov/mmwr/volumes/69/wr/mm6914e4.htm?s_cid=mm6914e4_w

[10] Multisystem Inflammatory Syndrome in U.S. Children and Adolescents https://www.nejm.org/doi/pdf/10.1056/NEJMoa2021680

[11] Pediatric Asthma: A Global Epidemic https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7052318/

[12] Asthma and COVID: What Are the Important Questions? https://www.jaci-inpractice.org/article/S2213-2198(20)30606-1/fulltext.

[13] Association of asthma and its genetic predisposition with the risk of severe COVID-19 https://www.jacionline.org/article/S0091-6749(20)30806-X/pdf.

[14] Age-specific incidence of allergic and non-allergic asthma https://bmcpulmmed.biomedcentral.com/articles/10.1186/s12890-019-1040-2.

[15] California Department of Public Health, 2017. Disinfectants and Work-Related Asthma: Information for Workers. https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/WRAPP/CDPH%20Document%20Library/DisinfectantsWRAWorkers.pdf.

[16] An analysis of SARS-CoV-2 viral load by patient age https://zoonosen.charite.de/fileadmin/user_upload/microsites/m_cc05/virologie-ccm/dateien_upload/Weitere_Dateien/analysis-of-SARS-CoV-2-viral-load-by-patient-age.pdf

[17] https://www.epa.gov/pesticide-registration/list-n-disinfectants-use-against-sars-cov-2-covid-19.

[18] References for box: California Department of Public Health, 2017. Disinfectants and Work-Related Asthma: Information for Workers.

https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/OHB/WRAPP/CDPH%20Document%20Library/DisinfectantsWRAWorkers.pdf. Holm, S.M., Leonard, V., Durrani, T. and Miller, M.D., 2019. Do we know how best to disinfect child care sites in the United States? A review of available disinfectant efficacy data and health risks of the major disinfectant classes. American journal of infection control, 47(1), pp.82-91. https://www.ajicjournal.org/article/S0196-6553(18)30731-4/fulltext#sec0018. Bernard, A., Carbonnelle, S., Michel, O., Higuet, S., De Burbure, C., Buchet, J.P., Hermans, C., Dumont, X. and Doyle, I., 2003. Lung hyperpermeability and asthma prevalence in schoolchildren: unexpected associations with the attendance at indoor chlorinated swimming pools. *Occupational and environmental medicine*, *60*(6), pp.385-394. https://oem.bmj.com/content/oemed/60/6/385.full.pdf. Agency on Toxic Substances and Disease Registry, 2008. ToxFAQs for Phenol. https://www.atsdr.cdc.gov/toxfaqs/TF.asp?id=147&tid=27. Agency on Toxic Substances and Disease Registry, 2008. ToxFAQs for Chlorophenol. https://www.atsdr.cdc.gov/toxprofiles/tp107-c1.pdf. Association of Occupational and Environmental Clinics (AOEC), *Exposure Code Lookup Database*, http://www.aoecdata.org/ExpCodeLookup.aspx. Culver, A., Geiger, C., Simon, D., 2014. Safer Products and Practices for Disinfecting and Sanitizing Surfaces, SF Environment, San Francisco, CA. https://sfenvironment.org/sites/default/files/fliers/files/sfe_th_safer_products_and_practices_for_disinfecting.pdf.

[19] Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1 https://europepmc.org/backend/ptpmcrender.fcgi?accid=PMC7121658&blobtype=pdf.

[20] https://www.epa.gov/coronavirus/can-i-use-fumigation-or-wide-area-spraying-help-control-covid-19.

[21] https://www.epa.gov/sites/production/files/2015-09/documents/fogger-mister-final-signed-letter.pdf.

[22] https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html.

[23] https://www.epa.gov/sites/production/files/2015-08/documents/usepa-opp-hed_residential_sops_oct2012.pdf.

[24] https://blog.zogics.com/electrostatic-disinfecting-sprayers-frequently-asked-questions.

[25] https://www.epa.gov/pesticide-registration/expedited-review-adding-electrostatic-spray-application-directions-use

[26] Ford, B.D. and Sopha, K., 2020. An evaluation of conventional cleaning and disinfection and electrostatic disinfectant spraying in K-12 schools. *Canadian Journal of Infection Control*, *35*(1). https://web.a.ebscohost.com/abstract?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=11835702&AN=142657811&h=Xz3O6WjftSLLvuyES%2bMT%2bnDhzKbQUhlOgdC%2fBJ2%2f%2bVuk0LoaWcYXh%2f6ZFy8gc6XxGPXt%2bvI%2bujfF9dNCkcoaxQ%3d%3d&crl=c&resultNs=AdminWebAuth&resultLocal=ErrCrlNotAuth&crlhashurl=login.aspx%3fdirect%3dtrue%26profile%3dehost%26scope%3dsite%26authtype%3dcrawler%26jrnl%3d11835702%26AN%3d142657811.

[27] Xi, J., Si, X. and Longest, W., 2014. Electrostatic charge effects on pharmaceutical aerosol deposition in human Nasal–Laryngeal airways. *Pharmaceutics*, *6*(1), pp.26-35. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3978523/.

[28] Chan, T.L., Lippmann, M., Cohen, V.R. and Schlesinger, R.B., 1978. Effect of electrostatic charges on particle deposition in a hollow cast of the human larynx-tracheobronchial tree. *Journal of Aerosol Science*, *9*(5), pp.463-468. https://d1wqtxts1xzle7.cloudfront.net/47593920/0021-8502_2878_2990009-520160728-22702-1iv5yqz.pdf?1469717459=&response-content-disposition=inline%3B+filename%3DEffect_of_electrostatic_charges_on_parti.pdf&Expires=1596146225&Signature=Mkz6MxAnTDqXecZxarBpGrmHUDVUhsi4Kr45DEj-CdwemvUO3V7WRZI8xo4XCq3-ozBhZpAqx4~B1RjSLYgM83dEmSUoSD9ieFCMONcMI2yboSRL2eNubURF4Y-7uI-ksgyEae-UqMgMyOmpRqkOpVoAgpdL8XMjwsY0exR8N-PPrVxvUOPj3VfjkIMcLxKQfxyLkvPp4slS5DJvGw-s7Jx~wTBRYNJKmpooM2R4YlEFjnEa2q1k0294YZM9ZQjDebBNzEE5avkQPSgRepn7xkvOu-VjGdO2tCNYkaqrV69NGgmn16h-ODHqfAsMDWmrmjfsxPbrpKM18bK4Cv99jQ__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA.

[29] https://blog.zogics.com/electrostatic-disinfecting-sprayers-frequently-asked-questions.

[30] Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1 https://europepmc.org/backend/ptpmcrender.fcgi?accid=PMC7121658&blobtype=pdf.

[31] Heald-Sargent T, Muller WJ, Zheng X, Rippe J, Patel AB, Kociolek LK. Age-Related Differences in Nasopharyngeal Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Levels in Patients With Mild to Moderate Coronavirus Disease 2019 (COVID-19). *JAMA Pediatr.* Published online July 30, 2020. doi:10.1001/jamapediatrics.2020.3651. https://jamanetwork.com/journals/jamapediatrics/fullarticle/2768952.

[32] National Center for Education Statistics, Schools and Staffing Survey for 2007-2008. https://nces.ed.gov/surveys/sass/tables/sass0708_2009324_t1s_08.asp.

[33] National Center for Education Statistics, Schools and Staffing Survey for 2007-2008. https://nces.ed.gov/surveys/sass/tables/sass0708_035_s1s.asp.

[34] EPA says, "Adequate experimental data is available to show that air sanitizers do not sterilize, disinfect, act as a germicide, or protect experimental animals from infections by airborne bacteria or viruses. Thus, claims of value in

preventing or treating diseases, or providing any other health protection, whether expressed or implied, are not acceptable. Claims must clearly indicate the mitigating nature of the activity, such as 'Temporarily reduces the number of airborne bacteria.'" https://www.epa.gov/pesticide-registration/efficacy-data-and-labeling-requirements-air-sanitizers.

[35] https://beyondpesticides.org/programs/antibacterials/disinfectants-and-sanitizers and https://beyondpesticides.org/assets/media/documents/Protecting%20Yourself%20from%20COVID-19%20(coronavirus)%207.7.20.pdf.

[36] https://www.epa.gov/coronavirus/how-can-members-my-household-use-disinfectants-properly-control-covid-19-if-family.

[37] How can airborne transmission of COVID-19 indoors be minimised? https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7250761/.

[38] https://www.epa.gov/coronavirus/indoor-air-and-coronavirus-covid-19.

[39] https://www.epa.gov/coronavirus/indoor-air-homes-and-coronavirus-covid-19.

[40] Lu, J., Gu, J., Li, K., Xu, C., Su, W., Lai, Z., Zhou, D., Yu, C., Xu, B. and Yang, Z., 2020. COVID-19 outbreak associated with air conditioning in restaurant, Guangzhou, China, 2020. *Emerging infectious diseases*, *26*(7), p.1628. https://wwwnc.cdc.gov/eid/article/26/7/20-0764_article.

[41] https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-reopening-schools-and-universities-c19-guidance.pdf. See also https://www.ashrae.org/technical-resources/filtration-and-disinfection-faq.

[42] More on filtration and UV disinfection: https://www.ashrae.org/technical-resources/filtration-and-disinfection-faq.

[43] https://www.ashrae.org/file%20library/technical%20resources/covid-19/practical-guidance-for-epidemic-operation-of-ervs.pdf

[44] https://www.ashrae.org/technical-resources/transportation.

[45] https://www.ashrae.org/technical-resources/transportation.